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Towards chipification: the multifunctional body art of the Net Generation

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Abstract
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TOWARDS CHIPIFICATION

The Multifunctional Body Art of the Net Generation

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Abstract. This paper considers the trajectory of the microchip within the context of converging disciplines to predict the realm of likely possibilities in the short-term future of the technology. After presenting the evolutionary development from first generation to fourth generation wearable computing, a case study on medical breakthroughs using implantable devices is presented. The findings of the paper suggest that before too long, implantable devices will become commonplace for everyday humancentric applications. The paradigm shift is exemplified in the use of microchips, from their original purpose in identifying humans and objects to its ultimate trajectory with multifunctional capabilities buried within the body.

1. Introduction

The decrease in cost and continual miniaturization of information technologies has meant that humans can now manageably carry numerous devices including laptop computers, personal digital assistants (PDAs), mobile phones and smart cards. Indeed the list of devices that consumers are carrying is rapidly growing, as are those that can be physically worn. Emerging devices such as smart apparel in the form of global positioning systems (GPS) wristwatches or radio-frequency identification (RF/ID) pendants are among the new gadgetry available to "find the nearest" or "locate you" anywhere/ anytime. Science fiction films dating back to the 1960s made predictions about the trajectory of such technologies, often considered wild and bizarre by some technology experts. However, beyond luggables and wearables we are now witnessing the introduction of implantables. The so-called "chipification" of humans is set to revolutionize location-based services (LBS), independent of the controversy it has caused since its wider inception at the beginning of the millennium. There are individuals who have already opted to implant themselves for ease of identification during emergency situations and there are a plethora of new start-up companies who are ready to "cash-in" on the idea. Such concrete evidence points to the rise of the *electrophorus*, a willing but not necessarily informed bearer of "electric" technology (Michael & Michael 2005).

2. The Rise of Wearable Computing

According to Siewiorek (1999, p. 82) the first wearable device was prototyped in 1961 at MIT (Massachusetts Institute of Technology) by Edward Thorp and Claude Shannon. The idea for the device came in 1955 in an attempt to be able to predict roulette. However, the term "wearable computer" was first used by a research group at Carnegie Mellon University in 1991, coinciding with the rise of the laptop computer (early models of which were known as "luggables"). Wearable computing can be defined as: "anything that can be put on and adds to the user's awareness of his or her environment… mostly this means wearing electronics which have some computational power" (Sydänheimo et al. 1999, p. 2012). While the term "wearables" is generally used to describe wearable displays and custom computers in the form of necklaces, tie-pins and eyeglasses, it is the opinion of the researchers that the definition should be broadened to incorporate PDAs (personal digital assistants), e-wallets, and other mobile accessories such as cellular phones and smart cards that require the use of belt buckles or satchels attached to conventional clothing.

Before the widespread diffusion of personal computers (PCs) and laptops it was auto-ID devices in the form of bar code cards, magnetic-stripe cards and smart cards that were 'luggable' and to some degree wearable with the aid of an external clip or fastener. In the case of contactless smart cards they could even be carried in a wallet or purse or in a trouser or shirt pocket. While they did not have the same processing power as PCs or laptops, auto-ID devices did point to a practical ideal, in terms of their size. IBM and other computer manufacturers have quickly caught onto the notion of wearable computing- their vision of a portable computer that could be worn instead of carried has been well-documented. According to Phil Hester of IBM's Personal Systems Group, the wearable PC, a hybrid device, would allow a user to freely walk around a building connected to a wireless network and perform all the day-to-day functions like send emails but with the added option of voice navigation/recognition (Wilcox 1999, p. 1). It is predicted that highly mobile professionals will soon take advantage of smart devices that will be built into their clothing so that they will be able to "…check messages, finish a presentation, or browse the Web while sitting on the subway or waiting in line at a bank" (Schiele et al. 2001, p. 44). Wearable computing is about to reinvent the way we work and go about our day-to-day business, just like auto-ID devices did in the 1970s and 1980s.

2.1. FIRST GENERATION: NOTEBOOKS, MOBILE PHONES, PDAS & PAGERS

Early prototypes of wearable computers throughout the 1980s and 1990s could have been described as outlandish, bizarre, abnormal-looking or even weird. For the greater part, wearable computing efforts have focused on head-mounted displays (a visual approach) that unnaturally interfered with human vision and made proximity to others cumbersome (Sawhney and Schmandt 1997, p. 171). But the long-term aim of research groups is to make wearable computing inconspicuous as soon as technical improvements allow for it. The end user should look as 'normal' as possible (Mann 1997, p. 177). This is where auto-ID techniques like voice recognition have been very useful. One need only consider the size of the first mobile phones in the early 1990s; they weighed the size of a small brick, were expensive, and very few people thought that widespread diffusion would be achieved. Yet today, numerous countries have reached in excess of 70 per cent penetration, which equates to a mobile phone for almost every adult in that country. As Cochrane (1999, p. 1) observed, "[t]oday, mobiles are smaller than a chocolate bar and cost nothing, and we can all afford them. And they are not bolted into vehicles as was originally conceived, but kept in pockets and hung on trouser belts." In fact, today it is commonplace to find professionals and younger technology-savvy students not only carrying mobile phones but notebooks, PDAs, iPods, and even smart flash storage cards/keys. To this list Starner (2001a, p. 46) adds a pager, electronic translator and calculator wristwatch. Starner even makes the observation that "[s]ome people wear too many computers." He noted that these separate computers have similar components such as a microprocessor and memory. In other words, there is a fair amount of redundancy in the separate devices. Wearable computers of the future will integrate all these functions into the one unit. The hope of wearable device developers is that the capabilities will converge to such an extent that the user will not consider the mobile phone as separate from a PDA or a PDA separate from a notebook. Nokia's 9001 Communicator is an example of this convergence. It has the combinatory functionality to act as a phone, pager, diary, music player, and digital camera all in the one unit.

2.1.1. Industrial Application

Wearable computers should not just be considered solely for personal electronics but suitable for industrial purposes as well. Several companies like Symbol Technologies, Honeywell and Xerox have researched industrial wearable devices for over a decade, along with newer names completely focused to this cause including Xybernaut and ViA. Perhaps one of the most well-known industrial uses of wearable computing is the United Parcel Service (UPS) case study. In 1995, UPS challenged Symbol Technologies to create a Wearable Data Collection device for their package loaders. Symbol's goal "was to create a wearable system that increased efficiency and productivity through mobility and hands-free computing and scanning" (Stein et al. 1998, p. 19). After considerable feedback between users at UPS and Symbol and evaluations for possible disease transmission given the wearable computer would assume skin contact, the Wrist Computer was released in 1996. At one point Symbol was shipping about seventeen thousand units per month to UPS, such was the success of the product. What is interesting to note is that Stein et al. (1998, p. 24) report that the "[t]he initial response from users who had been using hand-held computers was to not want to give up the wearable once they tried it." Perhaps the same can be said for other wearable devices. How many individuals can do without their mobile phones today, or PDAs, or smart transaction cards?

2.2. SECOND GENERATION: E-WALLETS AND GPS / RFID WRISTWATCHES

As wearable computing devices get smaller and smaller there has been a conscious effort to create an electronic wallet that combines the traditional wallet, the computer and communication technology (exhibit 1). For some time many believed that the Mondex smart card system would act to revolutionize the way people exchanged money. AT&T was so convinced that it invested in developing an electronic wallet. The "Mondex Wallet allows users to perform on-line transactions and view balance and transaction information stored on their card" (Cooper 1999, p. 87). The Mondex Wallet has not reached its potential diffusion rates but this has more to do with market maturity than anything else. While the Wallet is not the sophisticated type of wearable device that Mann and others envision, it is an incremental step towards that vision.

Swatch has also introduced an electronic wallet in the form of a wristwatch, known as Swatch Access. The wristwatch features a "miniature antenna and a computer chip, similar to those used in conventional smart card payment systems. This allows users to perform transactions using money stored on the chip" (Cooper 1999, p. 87). Trials of the watch have taken place in Finland's transport system. Another more sophisticated wristwatch solution known as, Digital Angel, "offers a unique combination of GPS, wireless Internet and sensor technologies" (ADS 2002a). The all-in-one unit which looks like a conventional watch can monitor temperature, contains a boundary alert function and has panic button feature. The versatility of the technology is seen in its wide range of formats and configurations such as a pager-like device, necklace, pendant, bracelet, and even belt buckle (ADS 2002a).

2.2.1. Biomedical Application

Wearables have also found a niche market in medical applications. Hinkers et al. (1995, p. 470) describes a small wearable device that continuously monitors glucose levels so that the right amount of insulin is calculated for the individual reducing the incidence of hypoglycaemic episodes. Hinkers once predicted the use of automated insulin delivery systems as well which are currently under development. Medical wearables even have the capability to check and monitor 26 different products in one's blood (Ferrero 1998, p. 88). Today medical wearable device applications include (Martin et al. 2000, p. 44):

> …monitoring of myocardial ischemia, epileptic seizure detection, drowsiness detection… physical therapy feedback, such as for stroke victim rehabilitation, sleep apnea monitoring, long-term monitoring for circadian rhythm analysis of heart rate variability (HRV).

For a detailed overview of these solutions refer to *Biomimetic Systems: Implantable, Sophisticated, and Effective* (IEEE 2005). Some of the current shortcomings of medical wearables are similar to those of conventional wearables, namely the size and the weight of the device is too heavy. In addition wearing the devices for long periods of time can be irritating due to the number of sensors that may be required to be worn for monitoring. The gel applied for contact resistance between the electrode and the skin can also dry up causing nuisance. Other obstacles to the widespread diffusion of medical wearables include government regulations and the manufacturers' requirement for limited liability in the event that an incorrect diagnosis is made by their equipment. More recently the issue of privacy has been raised especially for medical wearable devices that are applied within shared hospital facilities where access to results could be abused.

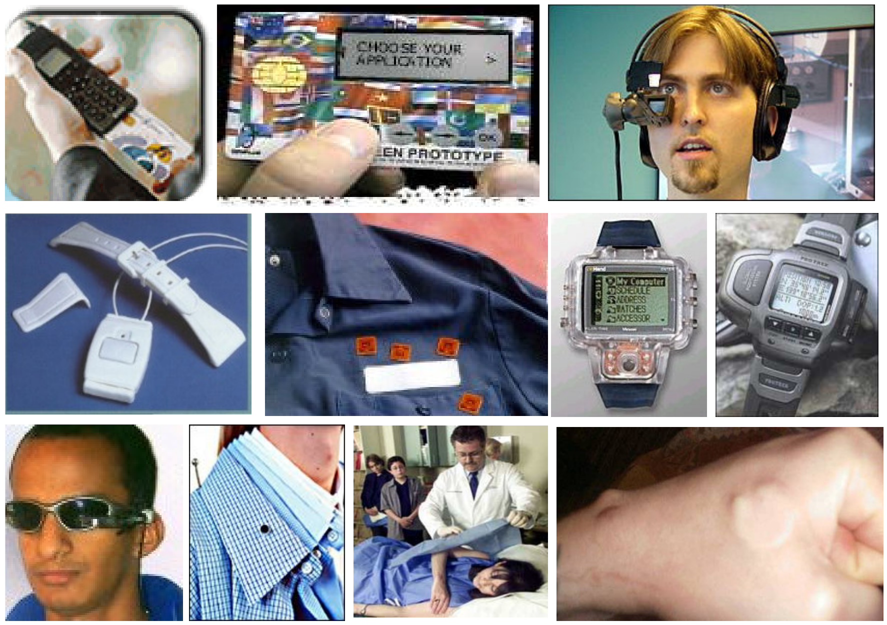

Exhibit 1. A collage of wearable and implantable devices

2.3. THIRD GENERATION: SMART CLOTHES AND ACCESSORIES

There are two things we carry with us everywhere we go, that is, clothes (such as undergarments, shirts, pants and accessories) and our actual bodies (composed of skin, muscles, nerves, water). Wearable computing experts have always sought a seamless and transparent way to introduce their high-tech devices. Many wearable computing developers believe the answer lies in distributing the equipment evenly throughout the body so that it does not feel excessively heavy for the end-user or look cumbersome. Known as "smart clothes" or "underwearables", they will do more than keep you warm. "With the help of computers and special high-tech fabrics, smart clothes could send and receive information and adjust to give you what you need at any moment" (Kastor 2000, p. 1). A research group in Belgium has been developing the "i-Wear" range (i.e. Intelligent Wear). Siddle (2000, p. 1) reports that the clothes:

> will perform many of the current functions of mobile phones, computers and even hospital monitoring equipment… The company [i-Wear] says the range of tasks that the

> clothes will be able to perform is vast, from taking phone calls to keeping a check on the health of the wearer.

While mass-scale commercial production of such clothes is probably a decade away, shirts with simple memory functions have been developed and tested. Sensors will play a big part in the functionality of the smartware helping to determine the environmental context and undergarments closest to the body will be used for body functions such as the measurement of temperature, blood pressure, heart and pulse rates. For now however, the aim is to develop ergonomically-astute wearable computing that is actually useful to the end-user. Head-mounted displays attached to the head with a headband may have acted to prototype the capabilities of wearable computing but it was not practical and definitely not attractive. Displays of the next generation will be mounted or concealed within eyeglasses themselves (Spitzer et al. 1997, p. 48). Accessories like ear-rings, cuff-links, tie-pins and pendants are also considered wearables if they contain intelligence. The Gesture Pendant, for instance, can be used in an "Aware Home" granting occupants the ability to be recognised and their activities interpreted to improve the quality of their life. The wearer has the ability to control different house elements like lights, the television, radio, telephone via simple hand gestures that are detected and interpreted by the smart pendant. The target audience for the Gesture Pendant is the elderly or disabled who suffer from particular ailments but who would still want to maintain their independence by living in their own homes. The device could be also used for medical monitoring over time.

2.3.1. Military Application

The military is paying particular attention to wearable computing developments. Combatants of the future may look like something/someone out of a film like "Universal Soldier". This should not be surprising since as far back as the 1960s there were attempts to make a "Man Amplifier"; to grant a soldier the added help of an exoskeleton, a sort of first line of defense in protection of the mortal flesh. While the Man Amplifier was unsuccessful due to obvious technological limitations of the time, today systems like FREFLEX (Force Reflecting Exoskeleton) are being trialed to augment human strength characteristics (Repperger et al. 1996, pp. 28-31). The US Army for instance, has been involved in trying to build a military uniform that utilize wearable computing components. They are seeking a uniform that can make (LoBaido 2001, p. 1):

> …soldiers nearly invisible, grant superhuman strength and provide instant medical care… All this would be achieved by developing particle-sized materials and devices- called "nanotechnology"- nestled into the uniform's fabric… Supercharged shoes could release energy when soldiers jump… Microreactors could detect bleeding and apply pressure… Light-deflecting material could make the suit blend in with surroundings.

This may sound highly exaggerated or Hollywood-*esque* but it is not. A British company which has called itself the Electronic Shoe Company has developed a pair of walking boots that can be used to power electrical equipment such as a mobile phone. Footwear could also be used to help orientate the soldier, leading them to specific targets through the safest possible route, with the capability of even detecting landmines. In the event of injury to a soldier it is hoped that smart shirts like the Sensate Liner (in which is woven optical fiber) can even aid to localize life-threatening wounds to the upper torso (Gorlick 1999, p. 121). According to Kellan (2000, p. 1) each soldier would be equipped with a wearable computer, GPS locator and wireless connections to the military network. This would grant individuals the ability to send signals back to base camp in times of trouble or for base camp to send new instructions to the soldier based on more up-to-date intelligence reports. It is not inconceivable for whole divisions to be redirected to areas of safety, minimizing the potential loss of life.

2.4. FOURTH GENERATION: PASSIVE AND ACTIVE IMPLANTABLE CHIPS

A new line of "wearables" is now emerging that does not quite fit the definition of the traditional wearable that assumes a presence outside the human body. Implantable devices such as RF/ID transponders cannot exactly be referred to as "wearables" because the component is not worn, rather it is ingrained, embedded, entrenched in the human body. The implant device is more than an extension; it becomes one with the body, a seamless fusion between flesh and foreign object. Years ago, automated biometric recognition techniques were heralded as a coming together of humans and machines but today we have something beyond a meeting point, we have the potential for a union of biological proportions on an evolutionary scale. The term "cyborg" seems to have been hijacked by science fiction novels and movies to mean "part machine, part human".

> Saffo, director of the Institute for the Future, does not doubt that people may become a race of cyborgs- "part man and part machine"… "We put all sorts of implants in [our bodies] today," says Saffo. "If we have metal hips, it only makes sense to have chips in, too" (Eng 2002).

2.4.1. Security Application

Applied Digital Solutions first announced its Verichip subdermal solution on December 19, 2001. Since then the company has mainly focused on offering medical-related applications through their frontline product VeriMed. More recently the VeriGuard security solution has helped employers protect their organizational assets in real-time by requesting the chipification of their staff. Two employees working for an Ohio video surveillance company CityWatcher.com (Gardner 2004) and one hundred and sixty employees of Mexico's Attorney General's office have been implanted to increase the layers of security, especially physical access control (Magnet 2006). According to Verichip's Vice President of Marketing in 2004, about seven thousand Verichips had been sold worldwide, of which about one thousand had actually been implanted in humans. The Chief Technology Officer (CTO) of VeriChip told Scheeres (2002, p. 1) that "[t]he chip… is injected into the subject's forearm or shoulder under local anesthesia during an outpatient procedure and leaves no mark." The VeriChip sells at a low two hundred US dollars with the Digital Angel service packaged at a monthly $29.95 US dollars with a one year minimum contract (Associated Press 2002; Farrell 2002). Scanners that could identify the VeriChip, very similar to those used to identify pet implants would cost between one thousand and three thousand US dollars. In 2003, VeriChip begun to aggressively market their products in the United States via the "Get

Chipped™" promotion. This campaign saw a large bus name the ChipMobile™ roam the US to increase the awareness level of the general public. The ChipMobile visited "recreation and stadium events, health clinics, nursing homes" among other locations (ADS 2002c).

3. Case Study: Medical Implantables

3.1. BIOCHIPS FOR DIAGNOSIS AND SMART PILLS FOR DRUG DELIVERY

It is not unlikely that biochips will be implanted at birth in the not-too-distant future. "They will be able to diagnose disease with precision, pre-determine a patient's response to treatment and make individual patients aware of any pre-disposition to susceptibility" (Wales 2001). With response to treatment for illness, drug delivery will not require patients to swallow pills or take routine injections; instead chemicals will be stored on a microprocessor and released as prescribed. The idea is known as "pharmacy-on-a-chip" and was founded by scientists at the Massachusetts Institute of Technology (MIT) in 1999 (LoBaido 2001, part 2, p. 2). The following extract is from The Lab (1999):

> Doctors prescribing complicated courses of drugs may soon be able to implant microchips into patients to deliver timed drug doses directly into their bodies.

Microchips being developed at Ohio State University (OSU) can be swathed with a chemical substance like pain medication, insulin, different treatments for heart disease, or gene therapies, allowing physicians to work at a more detailed level that is possible today (Swissler 2000, p. 1). The breakthroughs have major implications for diabetics especially who require insulin at regular intervals throughout the day. Researchers at the University of Delaware are working on "smart" implantable insulin pumps that may relieve people with Type I diabetes (Bailey 1999, p. 1). The delivery would be based on a mathematical model stored on a microchip and working in connection with glucose sensors that would instruct the chip when to release the insulin. The goal is for the model to be able to simulate the activity of the pancreas so that the right dosage is delivered at the right time. The implantable chips are also being considered as a possible solution to clinical depression and/or for patients who are incapable of committing to a prescribed regime. Gasson (1998, p. 1) first named this capability as "cyberdrugs"/ "cybernarcotics" with a well-meaning intent. Professor John Santini of MIT, knowing the possible implications of such an innovation, however, has repeatedly outlined that the focus is strictly "therapeutic", a better way to treat diseases (LoBaido 2001, part 2, p. 2). Scientists at universities are not the only ones researching biochips or smart pills according to Wales (2001) production is quickly becoming a big business as genomic-based medicine is the next buzz-word. Some of the more well-known players include: Affymetrix, Motorola Life Sciences Codelink Division, Packard BioScience, Agilent, and Hitachi.

3.2. COCHLEAR IMPLANTS- HELPING THE DEAF TO HEAR

More than thirty-two thousand people worldwide already have cochlear implants (Manning 2000, p. 7D). Cochlear implants can restore hearing to people who have severe hearing loss, a form of diagnosed deafness. Unlike a standard hearing aid that works like an amplifier, the cochlear implant acts like a microphone to change sound into electronic signals. Signals are sent to the microchip implant via RF stimulating nerve fibres in the inner ear. The brain then interprets the signals that are transmitted via the nerves to be sound. For a closer look at the cochlear implant see the Clarion and Nucleus product innovations. Another company, Canadian-based Epic Biosonics, has teamed up with Professor Chris Toumazou of Imperial College. Toumazou has made significant inroads to cutting the costs of cochlear implants and making them more comfortable for the individual. Most cochlear implants today require power packs worn on belts with connecting wires generated by battery power that generally do not look aesthetically good, Toumazou is trying to change this impracticality (Imperial College 1999, p. 2). For now, cochlear implants are being used to overcome deafness, tomorrow however they may be open to the wider public as a performance-enhancing technique. Audiologist, Steve Otto of the Auditory Brainstem Implant Project at the House Ear Institute in Los Angeles predicts that some day “implantable devices [will] interface microscopically with parts of the normal system that are still physiologically functional” (Stewart 2000, p. 2). He is quoted as saying that this may equate to “ESP for everyone.” Otto’s prediction that implants will one day be used by persons who do not require them for remedial purposes has been supported by numerous other high profile scientists.

3.3. RETINA IMPLANTS- ON A MISSION TO HELP THE BLIND TO SEE

The hope is that retina implants will be as successful as cochlear implants in the future. Like cochlear implants cannot be used for persons suffering from complete deafness, retina implants are not a solution for totally blind persons but rather those suffering from aged macular degeneration (AMD) and retinitis pigmentosa (RP). Retina implants have brought together medical researchers, electronic specialists and software designers to develop a system that can be implanted inside the eye (Ahlstrom 2000, p. 1). A typical retina implant procedure is as follows:

> [s]urgeons make a pinpoint opening in the retina to inject fluid in order to lift a portion of the retina from the back of the eye, creating a pocket to accommodate the chip. The retina is resealed over the chip, and doctors inject air into the middle of the eye to force the retina back over the device and close the incisions (Datamaster 2001, p. 1).

Brothers Alan Chow and Vincent Chow, one an engineer the other an ophthalmologist, developed the artificial silicon retina (ASR) and began the company Optobionics Corp in 1990. This was a marriage between biology and engineering, first conceived of over a Thanksgiving dinner. “In landmark surgeries at the University of Illinois at Chicago Medical Centre on June 28, the first artificial retinas made from silicon chips were implanted in the eyes of two blind patients who have lost almost all of their vision because of retinal disease.” In 1993 Branwyn (p. 3) reported that a team at the National Institute of Health (NIH) led by Dr. Hambrecht, implanted a 38-electrode array into a blind female's brain. It was reported that she saw simple light patterns and was able to make out crude letters. The following year the same procedure was conducted by another group on a blind male resulting in the man seeing a black dot with a yellow ring around it. Joseph Rizzo of Harvard Medical School's, Massachusetts Eye and Ear Infirmary has cautioned that it is better to talk down the possibilities of the retina implant so as not to give false hopes. The professor himself has expressed that they are dealing with "science fiction stuff" and that there are no long-term guarantees that the technology will ever fully restore sight, although significant progress is being made by a number of research institutes (Wells n.d., p. 5). Among these pioneers are researchers at The John Hopkins University Medical Centre in Baltimore, Maryland. Brooks (2001, pp. 4f) describes how the retina chip developed by the medical centre will work:

> …a kind of miniature digital camera… is placed on the surface of the retina. The camera relays information about the light that hits it to a microchip implanted nearby. This chip then delivers a signal that is fed back to the retina, giving it a big kick that stimulates it into action. Then, as normal, a signal goes down the optic nerve and sight is at least partially restored.

3.4. TAPPING INTO THE HEART AND BRAIN

If as far back as 1958, two transistors the size of an ice hockey puck were successfully implanted in the heart of a 43 year old man (Nairne 2000, p. 1), what will become possible by 2058 is bound by the imagination alone. Heart pacemakers are still being further developed today, but for the greater part, researchers are turning their attention to the possibilities of brain pacemakers. In the foreseeable future brain implants may help sufferers of Parkinson's, paralysis, nervous system problems, speech-impaired persons and even cancer patients. While the research is still in its formative years and the obstacles so great because of the complexity of the brain, scientists are hopeful of major breakthroughs in the next twenty to fifty years. The brain pacemaker endeavours are bringing together even more people from different disciplines headed mainly by neurosurgeons. By using brain implants electrical pulses can be sent directly to nerves via electrodes. The signals can be used to interrupt incoherent messages to nerves that cause uncontrollable movements or tremors. By tapping into the right nerves in the brain, particular reactions can be achieved. Using a technique that was first founded, almost accidentally in France in 1987, the following extract describes the procedure of "tapping into" the brain:

> Rezai and a team of functional neurosurgeons, neurologists and nurses at the Cleveland Clinic Foundation in Ohio had spent the next few hours electronically eavesdropping on single cells in Joan's brain attempting to pinpoint the precise trouble spot that caused a persistent, uncontrollable tremor in her right hand. Once confident they had found the spot, the doctors had guided the electrode itself deep into her brain, into a small duchy of nerve cells within the thalamus. The hope was that when sent an electrical current to the electrode, in a technique known as deep-brain stimulation, her tremor would diminish, and perhaps disappear altogether (Hall 2001, p. 2).

There are companies that have formed like Medtronic Incorporated (Minneapolis, Minnesota) that specialise in brain pacemakers. Medtronic's Activa implant has been designed specifically for sufferers of Parkinson's disease (Wells n.d., p. 3).

3.5. ATTEMPTING TO OVERCOME PARALYSIS

In more speculative research surgeons believe that brain implants may be a solution for persons who are suffering from paralysis such as spinal cord damage. In these instances the nerves in the legs are still theoretically "working", it is just that they cannot make contact with the brain which controls their movement. If somehow signals could be sent to the brain, bypassing the lesion point, it could conceivably mean that paralysed persons regain at least part of their capability to move (Dobson 2001, p. 2). In 2000 Reuters (pp. 1f) reported that a paralysed Frenchman [Marc Merger] "took his first steps in 10 years after a revolutionary operation to restore nerve functions using a microchip implant… Merger walks by pressing buttons on a walking frame which acts as a remote control for the chip, sending impulses through fine wires to stimulate legs muscles…" It should be noted, however, that the system only works for paraplegics whose muscles remain alive despite damage to the nerves. Yet there are promising devices like the Bion that may one day be able to control muscle movement using RF commands (D. Smith 2002, p. 2). Brooks (2001, p. 3) reports that researchers at the University of Illinois in Chicago have:

> …invented a microcomputer system that sends pulses to a patient's legs, causing the muscles to contract. Using a walker for balance, people paralysed from the waist down can stand up from a sitting position and walk short distances… Another team, based in Europe… enabled a paraplegic to walk using a chip connected to fine wires in his legs.

These techniques are known as functional neuromuscular stimulation systems.

3.6. GRANTING A VOICE TO THE SPEECH-IMPAIRED

Speech-impairment microchip implants work differently to that of the cochlear and retina implant. Whereas in the latter two, hearing and sight is restored, in implants for speech-impairment the voice is not restored, but an outlet for communication is created, possibly with the aid of a voice synthesizer. At The Emory University, neurosurgeon Roy E. Bakay and neuroscientist Phillip R. Kennedy have been responsible for the latest breakthroughs. In 1998, Versweyveld (p. 1) reported two successful implants of a neurotrophic electrode into the brain of a woman and man who were suffering from Amyotrophic Lateral Sclerosis (ALS) and brainstem stroke, respectively. In an incredible process, Bakay and Kennedy have somehow replicated the ability to explicitly capture the patient's thoughts to a computer screen by the movement of a cursor. "The computer chip is directly connected with the cortical nerve cells… The neural signals are transmitted to a receiver and connected to the computer in order to drive the cursor" (Versweyveld 1998, p. 1). This procedure has major implications for brain-computer interaction (BCI), especially bionics. Bakay predicts that by 2010 prosthetic devices will grant patients that are immobile the ability to turn on the TV just by thinking about it and by 2030 to grant severely disabled persons the ability to walk independently (Dominguez 2000, p. 2). Despite the early signs that these procedures may offer long term solutions for hundreds of thousands of people, some research scientists believe that tapping into the human brain is a long-shot. The brain is commonly understood to be "wetware" and plugging in hardware into this "wetware" would seem to be a type mismatch according to Steve Potter, a senior research fellow in biology working at the California Institute of Technology's Biological Imaging Centre in Pasadena. Instead Potter is pursuing the cranial route as a "digital gateway to the brain" (Stewart 2000, p. 1). Others believe that it is impossible to figure out exactly what all the millions of neurons in the brain actually do- but it should be reminded that this is the exact same argument that was presented when there were initial discussions about the Human Genome Project.

4. Chip Implants: From "Need" to "Want"

The case study in section 3 focused on medical implants that are attempts at "orthopedic replacements", corrective in nature, required to repair a function that is either lying dormant or has failed altogether. Implants of the future however, will attempt to add new "functionality" to native human capabilities, either through extensions or additions. Globally acclaimed scientists have pondered on the ultimate trajectory of microchip implants. The literature is admittedly mixed in its viewpoints of what *will* and *will not* be possible in the future; but one of the lessons that history has taught us is that if an idea has been conceived the probability that it will come into fruition is high; perhaps not tomorrow but eventually.

4.1. THE NATURAL TRAJECTORY

The predictions that are being made today can be traced back to the rather crude but advanced elucidations of the 1950s and 1960s. The only difference between the pronouncements of today and yester-year is that today scientists have the means to describe the finer details because of the technological advancements that have taken place since. Compare Ellul (1964) with Kaku (1998) and Warwick (2002) for instance in the following extracts:

> Knowledge will be accumulated in "electronic banks" and transmitted directly to the human nervous system by means of coded electronic messages. There will no longer be any need of reading or learning mountains of useless information; everything will be received and registered according to the needs of the moment. There will be no need of attention or effort. What is needed will pass directly from the machine to the brain without going through consciousness (Ellul 1964, p. 432).

> Is it possible to interface directly with the brain, to harness its fantastic capability? Scientists are proceeding to explore this possibility with remarkable speed. The first step in attempting to exploit the human brain is to show that individual neurons can grow and thrive on silicon chips. Then the next step would be to connect silicon chips directly to a living neuron inside an animal, such as a worm. One then has to show that *human* neurons can be connected to a silicon chip. Last… in order to interface directly with the

> brain, scientists would have to decode millions of neurons which make up our spinal cord (Kaku 1998, p. 112).
>
> On the 14th of March 2002 a one hundred electrode array was surgically implanted into the median nerve fibres of the left arm of Professor Kevin Warwick. The operation was carried out at Radcliffe Infirmary, Oxford, by a medical team headed by neurosurgeons Amjad Shad and Peter Teddy. The procedure, which took a little over two hours, involved inserting a guiding tube into a two inch incision made above the wrist, inserting the microelectrode array into this tube and firing it into the median nerve fibres below the elbow joint (Warwick).
>
> In particular extra memory and processing capabilities could be a possibility. A person's brain could be directly linked to a computer network (Warwick).

In essence, Ellul, Kaku and Warwick are pointing towards a technological trajectory which seems to have taken root of its own natural accord. They are all effectively articulating the same thing, except that we can observe a continual refinement of thought and projection from 'this is probably what will happen' (Ellul), to 'this is how you might go about it' (Kaku), to 'this is how the experiment was implemented' (Warwick).

5. The Net Generation- A Cultural Revolution

So why the requirement for implantable devices when the same devices could apparently be worn? Two opposing arguments have come from the same institution. Chief futurologist, Ian Pearson, of British Telecom (BT) is not convinced that implants will take the place of wearable components, whereas x-BT researcher, Peter Cochrane is convinced otherwise. Pearson's argument is that "[t]here is nothing you can do with embedded chips that you can't do with wearable ones" (LoBaido 2001, part 1, pp. 2f). Pearson however, does believe in the pervasive nature of the chips predicting that by 2006 wearable identity chips will be implemented. Only one year prior to this interview, Peter Cochrane told McGinity (2000, p. 17) that there

> "…will come a day when chips are not just worn around the neck, but are actually implanted under a human's skin." When I scoffed at such an idea as merely science fiction, Cochrane offered up that he himself would be testing out such a human chip and looked forward to the opportunity.

And who could ever doubt such a possibility after Warwick's 1998 Cyborg 1.0 trial? After the microchip implant Warwick was able to walk around his rigged up building in the Cybernetics department and be recognised as being "Kevin Warwick." As he walked through the doorways, the radio signal energised the coil in the chip, produced current, and gave the chip the ability to send out an identifying signal (Witt 1999, p. 2). Warwick and Cochrane are not alone in their efforts. Mieszkowski (2000, part 1, p. 2) writes:

> [m]any theorists see people carrying embedded technology as mobile computing's next "killer application"... Instead of just implanting machines into humans to reconstruct joints or regulate heartbeats, they imagine the addition of sensors and chips in bodies which will make people better, stronger and faster.

Warwick's Cyborg 2.0 project for instance, intended to prove that two persons with respective implants could communicate sensation and movement by thoughts alone. The prediction is that terminals like telephones would eventually become obsolete if thought-to-thought communication became possible. Warwick describes this as "putting a plug into the nervous system" (Dobson 2001, p. 1) to be able to allow thoughts to be transferred not only to another person but to the Internet and other mediums. While Warwick's Cyborg 2.0 may not have achieved its desired outcomes, it did show that a form of primitive Morse-code-style nervous-system-to-nervous-system communication is realizable (Green 2002, p. 3). Warwick is bound to keep trying to achieve his project goals given his philosophical perspective. And if Warwick does not succeed, he will have at least left behind a legacy and enough stimuli for someone else to succeed in his place, even if, as Berry (1996) says, the prediction will come true 500 years from now.

Today we speak of a Net Generation (N-Geners) who never knew a world without computers or the Internet (Tapscott 1998, p. 38); for them the digital world is like the air they breathe. What is important to N-Geners is not how they got to where they are today but what digital prospects the future holds. "[O]ur increasing cultural acceptance of high-tech gadgetry has led to a new way of thinking: robotic implants could be so advantageous that people might actually want to become cybernetic organisms, by choice. The popularization of the cyberpunk genre has demonstrated that it can be hip to have a chip in your head" (Trull 1998, p. 1). Amal Graafstra, the author of *RFID Toys* had two chips implanted (one in each hand) by his family doctor. He has the ability to access his computer, vehicle and front door using his implants. There are also blogs where members who have implants or are considering getting an implant, communicate about their RFID interests at http://tagged.kaos.gen.nz.

5.1 CHIPIFICATION AND ART

Mieszkowski (2000, part 2, p. 4) believes that "chipification" will be the next big wave in place of tattoos, piercing and scarification. In the U.S. it was estimated in 2001 that about two hundred Americans had permanently changed their bodies at around nine hundred dollars an implant, following a method developed by Steve Hayworth and Jon Cobb (Millanvoye 2001, p. 1). Canadian artist Nancy Nisbet has implanted microchips in her hands to better understand how implant technology may affect the human identity. The artist told Scheeres (2002d, pp. 1f), "I am expecting the merger between human and machines to proceed whether we want it to or not…" However, other artists like Natasha Vita More and Stelarc have ventured beyond localized chip implants. Their vision is of a complete prosthetic body that will comprise of nanotechnology, artificial intelligence, robotics, cloning and even nanobots (Walker 2001, p. 9). More calls her future body design Primo 3M Plus. Stelarc's live performances however, have been heralded as the closest thing there is to imagining a world where the human body will become obsolete.

> A Stelarc performance is not something you'd recommend for the kiddies before bedtime. It usually involves a disturbing mix of amplified sounds of human organs and techno beats, an internal camera projecting images of his innards, perhaps a set of robotic legs or an extra arm, or maybe tubes and wires connecting the performer's body to the internet

> with people in another country manipulating the sensors, jerking him into a spastic dance. It's a dark vision, but it definitely makes you think (Walker 2001, p. 6).

6. Defining the Electrophorus- Who or What?

The human who has been implanted with a microchip is an *Electrophorus*, a bearer of "electric" technology. One who "bears" (i.e. a phorus) is in some way intrinsically or spiritually connected to that which they are bearing, in the same way an expecting mother is to the child in her womb. The root "electro" comes from the Greek word meaning "amber," and "phorus" means to "wear, to put on, to get into". To electronics something is "to furnish it with electronic equipment" and electrotechnology is "the science that deals with practical applications of electricity". The Macquarie Dictionary definition of electrophorus is "an instrument for generating static electricity by means of induction." The term "electrophoresis" has been borrowed here, to describe the act that an electrophorus is involved in. McLuhan et al. (1995, p. 94) believed that "…electricity is in effect an extension of the nervous system as a kind of global membrane." The term electrophorus seems to be much more suitable today than that of any other term, including that of cyborg. And although implants are not exactly "electronic", the systems they communicate with cannot run without electricity (exhibit 2).

Exhibit 2. Advertising Campaigns Targeted at the Net Generation (N-Geners)

6.1. BEYOND CHIP IMPLANTS

Beyond chip implants for tracking there are the possibilities associated with neural prosthetics and the potential to directly link computers to humans. Rummler (2001, p. 1) asks whether it is ethical to be linking computers to humans in the first place and whether or not limitations should be placed on what procedures can be conducted even if they are possible. For instance, could this be considered a violation of human rights? And more to the point what will it mean in the future to call oneself "human". McGrath (2001, p. 2) asks "how human"?

> As technology fills you up with synthetic parts, at what point do you cease to be fully human? One quarter? One third?... At bottom lies one critical issue for a technological age: are some kinds of knowledge so terrible they simply should not be pursued? If there can be such a thing as a philosophical crisis, this will be it. These questions, says Rushworth Kidder, president of the Institute for Global Ethics in Camden, Maine, are especially vexing because they lie at "the convergence of three domains- technology, politics and ethics- that are so far hardly on speaking terms.

At the point of electrophoresis "[y]ou are not just a human linked with technology; you are something different and your values and judgement will change" (Brown 1999, p. 1). Some suspect that it will even become possible to alter behavior in people with brain implants (LoBaido 2001, part 2, p. 2), whether they will it or not. Maybury (1990, p. 7) believes that "[t]he advent of machine intelligence raises social and ethical issues that may ultimately challenge human existence on earth."

7. Conclusion

It has been shown that microchips have a trajectory that is, in part, radically different from the intent of the inventors. Initially attached to non-living things and later adopted to be carried by humans, it now seems inevitable that the components will become *one* with humans. Converging disciplines are making the realm of the "impossible", potentially "possible". Of course some resistance will be experienced initially but as society continues to change becoming more and more techno-centric, it will decide what microchips will be used for, even if it has little to do with what it was originally designed (Branwyn 1993, p. 6). Society continues to be increasingly dependent on the promise of technology and it is difficult to see who and how many will resist the ultimate hope of "living for ever". It is important to note here that the accomplishment is not in the rise of the computer/information age, it is as Grier (2000, p. 83) puts it, in "the *vision*, it has maintained" (Grier 2000, p. 83). When the ENIAC was publicly announced in 1946, no one could predict its ultimate impact. The founder of IBM famously forecasted a worldwide market of five computers (Coughlin 2000, p. 1)! The same could be said for brain implants today but we should at least pay some respect to the instructive lessons of history. Perhaps what we really need to do is start afresh considering the implications that such developments may have without discounting them outright as an improbable science fiction or even at the other extreme, as a possible universal remedy. One reason this paper depended so heavily on quoting current research was to actually dispel the myth that this type of dialogue is premature. It obviously is not. The force of the momentum is such that continual attempts will be made to go beyond that which has been achieved. It is not enough to begin discussing possible implications when the technology reaches the early adoption stage- by then the technology would have taken root- as it seems to have done already to some degree. Ultimately humanity will have a choice, and as Warwick has openly stated, hopefully it will be an *individual choice*- for those who would like to remain mere *human* and those who would like to continue to *evolve*.

References

ADS.: 2002a, August 15, Responding to growing customer inquiries and media interest, Applied Digital Solutions highlights anti-kidnapping potential of its “Personal Safeguard” Technologies, *Applied Digital Solutions,* http://www.adsx.com/news/2002/081602.html, [October 15, 2002], 1-5.

ADS.: 2002b, October 7, VeriChip Corporation will benefit from new United States patent (#6,400,338) awarded to Digital Angel Corporation- manufacturer of VeriChip™’, *Applied Digital Solutions,* http://www.adsx.com/news/2002/100702.html, [October 15, 2002], 1-3.

ADS.: 2002c, October 24, Verichip Corporation launches national “Get Chipped™” promotion, *Applied Digital Solutions,* http://www.adsx.com/news/2002/102402.html, [January 14, 2003], 1-4.

Ahlstrom, D.: 2000, November 9, Microchip implant could offer new kind of vision, *The Irish Times,* http://www.ireland.com/newspaper/science/2000/1109/sci1.htm, [November 20, 2001], 1-2.

Associated Press.: 2002, April 5, Company gets okay to sell ID-only computer chip implant, *The Detroit News,* http://www.detnews.com/2002/technology/0204/05/technology-57686.htm, [October 15, 2002].

Bailey, R.: 1999, June 10, Implantable insulin pumps, *Biology About.com.* http://biology.about.com/library/weekly/aa061099.htm, [May 1, 2001], 1-3.

Berry, A.: 1996, *The Next 500 Years: life in the coming millennium*. Gramercy Books, New York.

Branwyn, G.: 1993, The desire to be wired. *Wired* 1.4, http://www.eff.org/Net_culture/Cyborg_anthropology/cyber_modification.article, [November 29, 2001], 1-6.

Brooks, M.: 2001, November 14, The Cyborg cometh, *Worldlink: The Magazine of the World Economic Forum*, http://www.worldlink.co.uk/stories/storyReader$844, [November 29, 2001], 1-6.

Brown, J.: 1999, January 26, Professor Cyborg, *Salon.com|Technology*, http://www.salon.com/tech/feature/1999/10/20/cyborg/index2.html, [January 20, 2000], 1-10.

Cochrane, P.: 1999, *Tips For Time Travelers: visionary insights into new technology, life, and the future on the edge of technology,* McGraw-Hill, New York.

Cooper, L.: et al., 1999, *A run on Sterling- personal finance on the move,* The Third International Symposium on Wearable Computers, 87-93.

Coughlin, K.: 2000, January 4, The melding of man and machine, *The Star-Ledger*: The Newspaper for New Jersey, http://www.nj.com/page1/ledger/e1576d.html, [November 29, 2001], 1-3.

Datamaster.: 2001, July 20, More tests of eye implants planned, *BrainLand: The Neuroscience Information Centre*. http://www.brainland.com/indiv_news cfm?ID=351, [November 29, 2001], 1-2.

Dobson, R.: 2001, June 5, Professor to try to 'control' wife via chip implant, *Rense.com*, http://www.rense.com/general10/professortotry.htm, [October 15, 2002], 1-3.

Dominguez, A.: 2000, The brain as a remote control, *CBS News,* http://www.cbsnews.com/now/story/0,1597,249757-412,00.shtml, [November 29, 2001], 1-2.

Ellul, J.: 1964, *The Technological Society,* Vintage Books, New York.

Eng, P.: 2002, February 25, I, Chip? Technology to meld chips into humans draws closer, *ABCNEWS.com.* http://abcnews.go.com/sections/scitech/DailyNews/chipimplant020225.html, [October 15, 2002], 1-3.

Farrell, N.: 2001, December 20, Bionic man becomes a reality, *IT Week.* http://www.itweek.co.uk/News/1127877, [October 15, 2002].

Ferrero, J.L.: 1998, Wearable computing, *IEEE Micro*, 18(5), 87-88.

Gardner, W.D.: 2004, RFID Chips Implanted In Mexican Law-Enforcement Workers, *Information Week*, http://www.worldnetdaily.com/news/printer-friendly.asp?ARTICLE_ID=48760, [April 6, 2006], 1-3.

Gasson, M.: 1998, Implants and bioengineering. *Research- Implant,* http://www.madlab.rdg.ac.uk/madlab/research/implant.htm, [November, 29 2001], 1-2.

Gorlick, M.M.: 1999, Electric suspenders: a fabric power bus and data network for wearable digital devices, *The Third International Symposium on Wearable Computers*, 114-121.

Graafstra, A.: 2006, Amal Graafstra's Homepage, http://amal.net/rfid.html, [April, 6 2006], pp. 1-13.

Green, D.: 2002, August 2, Why I am not impressed with Professor Cyborg, *BBC News,* http://news.bbc.co.uk/2/hi/uk/2163947.stm, [May 4, 2003], 1-8.

Grier, D.A.: 2000, Anecdotes, *IEEE Annals of the History of Computing*, 82-85.

Hall, S.S.: 2001, September, Brain pacemakers, *An MIT Enterprise Technology Review,* http://www.technologyreview.com/magazine/sep01/hall.asp, [November 22, 2001], 1-6.

Hinkers, X. et al.: 1995, Microdialysis system for continuous glucose monitoring, *The 8th International Conference on Solid-State Sensors and Actuators, and Eurosensors IX. Stockholm*, Sweden, June 25-29, 470-473.

IEEE.: 2005, Biomimetic systems: implantable, sophisticated, and effective, *IEEE Engineering in Medicine and Biology*, 24(5), Sept/Oct.

Imperial College.: 1999, Micro-electronics behind novel bionic ear, *Imperial College News.* http://www.ic.ac.uk/templates/text_3.asp?P=2570, [November 29, 2001], 1-3.

Kaku, M.: 1998, *Visions: how science will revolutionize the 21st century and beyond,* Oxford University Press, Oxford.

Kastor, E.: 2000, December 28, Smarty-pants… and shirts, *WashingtonPost*. http://www.washingtonpost.com/ac2/, [May 29, 2001], 1-3.

Kellan, A.: 2000, October 19, Wearable gadgets offer modern look for military, *CNN.com,* http://www.cnn.com/2000/TECH/computing/10/19/wear.gadgets.t_t/index.html, [November 29, 2001], 1-2.

LoBaido, A.C.: 2001, Soldiers with microchips: British troops experiment with implanted, electronic dog tag, *WorldNetDaily.com*, http://www.fivedoves.com/letters/oct2001/chrissa102.htm, [November 20, 2001], 1-2.

Magnet, A..: 2006, Ohio company implants security chips into employees, *New York Sun*, http://www.nysun.com/article/27551, [April 6, 2006], 1-3.

Mann, S.: 1997, Eudaemonic computing ('underwearables'), *IEEE First International Symposium on Wearable Computers*, 177-178.

Manning, A.: 2000, May 2, The changing deaf culture: improved implants bring concern for a beautiful language, *USA Today*, 19.

Martin, T. et al.: 2000, Issues in wearable computing for medical monitoring applications: a case study of a wearable ECG monitoring device, *The Fourth International Symposium on Wearable Computers*, 43-49.

Maybury, M.T.: 1990, The mind matters: artificial intelligence and its societal implications, *IEEE Technology and Society Magazine*, June/July, 7-15.

McGinity, M.: 2000, Body of the technology: it's just a matter of time before a chip gets under your skin, *Communications of the ACM*, 43(9), 17-19.

McGrath, P.: 2001, Technology: Building better humans, *Newsweek*, http://egweb.mines.edu/eggn482/admin/Technology.htm, [Accessed 29 November], 1-3.

McLuhan, E. and Zingrone, F.: 1995, *Essential McLuhan,* BasicBooks, USA.

Michael, K.: 2004, Location-based services: a vehicle for IT&T convergence, *The Fourth International Conference on E-engineering & Digital Enterprise Technology*, Yorkshire, UK.

Michael, K. and Masters, A.: 2004, Applications of human transponder implants in mobile commerce, *Eighth World Multiconference on Systemics, Cybernetics and Informatics*, Orlando, Florida.

Michael, K. and Michael, M.G.: 2004, The social, cultural, religious and ethical implications of automatic identification, *Proceedings of the Seventh International Conference in Electronic Commerce Research*, 10-13th June: Dallas, Texas, 433-450.

Michael, K. and Michael, M.G.: 2005, Microchipping people: the rise of the electrophorus, *Quadrant*, March, 22-23.

Mieszkowski, K.: 2000, Put that silicon where the sun don't shine, *Salon.com,* http://www.salon.com/tech/feature/2000/09/07/chips/, vols 1-3, [November 11, 2001], 1-3.

Millanvoye, M.: 2001, Teflon under my skin', *UNESCO*, http://www.unesco.org/courier/2001_07/uk/doss41.htm, [Accessed 29 November 2001], 1-2.

Nairne, D.: 2000, October 10, Building better people with chips and sensors, *scmp.com*, http://special.scmp.com/mobilecomputing/article/FullText_asp_ArticleID-20001009174, [November 29, 2001], 1-2.

Repperger, D.W. et al.: 1996, Human tracking studies involving an actively powered, augmented exoskeleton, *IEEE Proceedings of the 1996 Fifteenth Southern Biomedical Engineering Conference, 28-31.*

Reuters.: 2000, March 20, Chip helps paraplegic walk, *Wired News* http://www.wired.com/news/technology/0,1282,35056,00.html, [November 29, 2001], 1-3.

Sawhney, N. and Schmandt, C.: 1997, Nomadic Radio: A spatialized audio environment for wearable computing. *IEEE First International Symposium on Wearable Computers*, 171-172.

Scheeres, J.: 2002, January 25, Kidnapped? GPS to the rescue. *Wired News*. http://www.wired.com/news/business/0,1367,50004,00.html, [October 15, 2002], 1-2.

Scheeres, J.: 2002d, 11 March, New body art: Chip implants, *Wired News*, http://www.wired.com/news/culture/0,1284,50769,00.html, [Accessed 15 October 2002], 1-2.

Schiele, B. et al.: 2001, Sensory-augmented computing: wearing the museum's guide, *IEEE Micro*, 44-52.

Siddle, J.: 2000, December 30, Clothes that do the thinking, *BBC News*, http://news.bbc.co.uk/hi/english/sci/tech/newsid_1092000/1092422.stm, [November 29, 2001], 1-3.

Siewiorek, D.P.: 1999, Wearable computing comes of age, *IEEE Computer*, May, 82-83.

Smith, D.: (2002, February 16). Chip implant signals a new kind of man, *The Age*. http://www.theage.com.au/news/national/2002/02/16/FFX9B13VOXC.html, [October 15, 2002], 1-2.

Spitzer, M.B. et al.: 1997, Eyeglass-based systems for wearable computing, *IEEE First International Symposium on Wearable Computers*, 48-51.

Starner, T.: 2001a, The challenges of wearable computing: part 1*, IEEE Micro*, July-August, 44-52.

Starner, T.: 2001b, The challenges of wearable computing: part 2, *IEEE Micro*, July-August, 54-67.

Stein, R. et al.: 1998, Development of a commercially successful wearable data collection system. *IEEE Second International Symposium on Wearable Computers*, 18-24.

Stewart, S.: 2000, February, Neuromaster, *Wired,* 8.02, http://www.wired.com/archive/8.02/potter.html, [November 29, 2001], 1-3.

Sun-Sentinel.: 2003, The smart pill. Sun-Sentinel News: *The Edge,* http://www.sun-sentinel.com/graphics/news/smartpill, [April 3, 2003].

Swissler, M.A.: 2000, September 8, Microchips to monitor meds, *Wired.* http://www.wired.com/news/technology/0,1282,39070,00.html, [November 29, 2001], 1-3.

Sydänheimo, L. et al.: 1999, Wearable and ubiquitous computer aided service, maintenance and overhaul, *IEEE International Conference on Communications,* (3), 2012-2017.

Tapscott, D.: 1998, *Growing Up Digital: the Rise of the Net Generation*, McGraw- Hill, New York.

The Lab.: 1999, January 28, Microchip implants for drug delivery, *News in Science,* http://www.abc.net.au/science/news/stories/s18502.htm, [November 20, 2001], 1-2.

Trull, D.: 1998, Simple Cyborg, *Parascope*, http://www.parascope.com/articles/slips/fs29_2.htm, [Accessed 20 November 2001], 1-4.

Versweyveld, L.: 1998, October 13, Chip implants allow paralyzed patients to communicate via the computer, *Virtual Medical Worlds Monthly,* http://www.hoise.com/vmw/articles/LV-VM-12-98-13.html, [October 15, 2002], 1-2.

Wakefield, J.: 2002, March 24, Chips to fight kidnapping, *BBC News Online,* http://news.bbc.co.uk/1/hi/sci/tech/1869457.stm, [November 13, 2003], 1-2.

Wales, E.: 2001, November 20, It's a living chip. *The Australian*, 4.

Walker, I.: 2001, Cyborg dreams: Beyond Human, Background Briefing *ABC Radio National*, 4 November, 1-15.

Warwick, K.: 1998, Professor Kevin Warwick, *The Department of Cybernetics: The University of Reading*, http://cyber.reading.ac.uk/K.Warwick/, [Accessed 27 October 1998].

Wells, W.: n.d., The chips are coming, *Biotech Applied,* http://www.accessexcellence.com/AB/BA/biochip.html, [May 22, 2001], 1-5.

Wilcox, J.: 1999, December 20, More details emerge on IBM's wearable PC, *CNet new.com.* http://news/cnet.com/news/0-1006-200-1501451.html, [November 29, 2001], 1-3.

Witt, S.: 1999, January 14, Is human chip implant wave of the future? *CNN.com.* http://www.cnn.com/TECH/computing/9901/14/chipman.idg/, [November 22, 2001], 1-4.